Thermal Loading Studies Using the Unsaturated Zone Model

Charles Haukwa, Yu-Shu Wu and Gudmundur S. Bodvarsson
Contact: Charles Haukwa, 510/486-2933, cbhaukwa@lbl.gov

OBJECTIVES

The purpose of this study was to develop a thermo-hydrological (TH) model of the unsaturated zone (UZ) at Yucca Mountain, Nevada, that can be used to evaluate the performance of the potential nuclear waste repository. The numerical model provides a prediction of: (1) temperatures over the mountain and the size of the two-phase zone; (2) the evolution of moisture and gas distribution; (3) the effects of heat on liquid and gas flow; (4) the potential for temperature-induced property changes; and (5) the effects of heat on perched water.

APPROACH

The model uses a 2-D north-south cross-section grid, based on the FY2000 UZ 3-D Flow and Transport Model, and employs the dual-continuum formulation with the active fracture model. The initial thermal load is 72.7 kW/acre. We allow for natural decay of the heat source, and pre-closure ventilation reduces the heat load by 70% during the first 50 years. The numerical grid allows the heat source to be applied at the discrete drift locations at the potential repository. The simulations of coupled heat and mass flow were conducted using TOUGH2 (EOS3 module) over a simulated period of 100,000 years.

RESULTS

The model predicts hot and dry conditions within the fractures close to drifts that last for hundreds of years, even with ventilation. Other modeling results include the following:

- Large temperature changes are predicted only directly above and below the repository (Figure 1). The temperature changes result in a two-phase zone that extends 20 m above the repository. Laterally, the thermally affected zone extends no more than 50 m from the repository.
- Completely dry matrix conditions are predicted at several locations. The dry-out zones are confined to within 10 m of the repository drifts and may last 1,000 years.
- Temperatures at the drifts are predicted to rise to boiling conditions (97°C) except in the low infiltration areas, where temperatures may rise to over 110°C. Temperatures between the drifts are predicted to rise to a maximum of 80-85°C after 1,000 years.
- The predicted maximum temperature is 70-75°C on top of the CHn (910 m), 65-70°C at the water table (730 m), and 40-45°C in the PTn (1300 m) after 5,000 years. The model predicts little potential for temperature-induced property changes in both the CHn and PTn.
- Enhanced liquid flux is only predicted close to the repository, where there is substantial drying of the matrix and fracture continua. The maximum fracture liquid flux towards the drifts is 300 mm/year after 10 years, but is all vaporized by repository heat. Liquid flow adjacent to the drifts may be enhanced by drainage of condensate.
- There is little potential for vaporization and mobilization of the perched water, except when the bodies are located close to the repository.

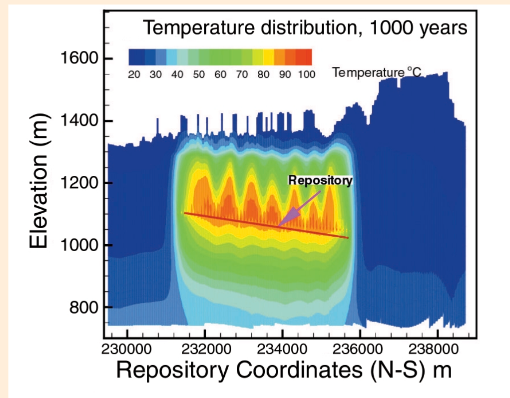

Figure 1. Predicted temperature distribution.

SIGNIFICANCE OF FINDINGS

The study demonstrates that TH processes associated with thermal loading of a repository in fractured unsaturated tuffs can be modeled using the dual-continuum approach, using the active fracture model concept. The model provides a prediction of a thermally affected zone and a map of the evolution of liquid and gas flux, temperature and liquid distribution in the mountain over a period of thousands of years. Such a model can serve as a predictive tool for assessment of alternative designs of the potential repository.

RELATED PUBLICATIONS

Haukwa, C., Mountain-scale coupled processes (TH) models, MDL-NBS-HS-000007, Las Vegas, Nev., CRWMS M&O, 1999.

Sonnenthal, E.L., and N. Spycher, Drift scale coupled processes (DST, THC seepage) models, MDL-NBS-HS-000001, Las Vegas, Nev., CRWMS M&O, 1999.

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